ECONOMIC AND BIOLOGICAL CONSEQUENCES OF ROAD BUILDING IN THE BOLIVIAN LOWLANDS: A RAPID ASSESSMENT METHOD

Documento Técnico 53 /1997

Mayo, 1997

Economic and Biological Consequences of Road Building in the Bolivian Lowlands: Assessment Method

Proyecto BOLFOR
Calle Prolongación Beni 149
Santa Cruz, Bolivia

USAID Contract : 511-0621-C-00-3027

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May, 1997

BOLFOR is funded by USAID and the Bolivian Government, and is implemented by Chemonics International, with technical assistance from Conservation International, Tropical Research and Development and Wildlife Conservation Society

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SECTION I
INTRODUCTION

The government of Bolivia, in cooperation with the United States Agency for International Development, is implementing the BOLFOR Project (*Proyecto de Manejo Forestal Sostenible*), an effort to use forest resources in a way that intelligently balances economic development with the conservation of natural ecosystems. This program provides technical assistance, policy advice and community development support, largely directed toward sustainably managing the supply of wood from natural forests in Bolivia's lowlands. The ultimate environmental objective is to avoid having forest land cleared for other uses.

Improving forest management can be a key ingredient to limiting forest conversion, but is rarely sufficient, because deforestation is usually the result of a dynamic interaction of several social, economic and political forces in a given ecosystem. Among the most important of these forces is the existence of transportation infrastructure providing access to a region for human settlers. This study suggests how roads can be rapidly assessed to determine the relative risk they pose to forest biodiversity and their likely economic benefits. A rapid assessment method of this nature can make a useful contribution to policy-making since it can provide a rough evaluation of environmental and economic consequences of infrastructure projects without the kind of expensive studies that can create pressure to build a project, regardless of its technical merits.

SECTION II
ROADS, WOODS AND DEVELOPMENT IN THE TROPICS

A. Economic Benefits

New or better roads can deliver important economic benefits locally, regionally and nationally. At the most basic level, they lower the cost of moving goods from one place to another. That makes consumer goods cheaper in the hinterlands, and allows food and natural resources to be priced more competitively in urban and export markets. Apart from raising rural incomes, roads can improve living standards in the countryside by making travel more affordable, and by providing better access to social services. At the regional level, efficient transportation allows complementary qualities of different regions to be more fully exploited, spurring development at both ends of the road. At the national level, well-planned road investments can increase the overall volume of trade by making both exporting and importing less expensive.

In practice, some road benefits far exceed the expectations of planners, while others fail to materialize. In a study of rural roads[1] in Panama, Honduras and Jamaica, Tuazon (1994a) found that gains to passenger transporters, freight transporters, passengers, large-scale farmers and part-time farmers were greater than expected. By several measures, improvements in rural quality of life met, but did not exceed expectations. These improvements included better access to social services, reduced travel times, reduced isolation and improved living conditions.

The largest disappointment was the overall lack of growth in agricultural investment and production, especially among small-scale farmers, which was usually the primary rational for the roads. That finding points to the fact that better transportation is just one element in agricultural development. Absent technical and financial services and access to markets, new roads often simply increase the rural subsistence population and the area of land incorporated into large farms and ranches.

It is clear that roads can have large and widely distributed benefits. The task for development planners is to determine where those benefits are likely to be greatest, and whether they will exceed the road's cost.

B. Environmental Costs: Deforestation

[1]A distinction is usually made between trunk roads, whose primary purpose is to connect economic centers, and rural roads, whose primary purpose is to improve the quality of rural life. Though useful conceptually, this distinction is blurry in Bolivia's lowlands. Road networks are sufficiently limited there, in that roads – proposed and existing -- linking department capitals, and even connecting to Peru and Brazil, perform the functions of both trunk and rural roads. Rationales for upgrading and extending these roads commonly cite agricultural expansion as the primary benefit.

Traditional cost-benefit analysis does not typically count all the costs -- nor all the benefits -- of road-building. Among the most important omissions are environmental costs. These may include direct costs such as soil eroding from road cuts and fouling watercourses and/or indirect costs such as the clearing of roadside forest for agriculture. The latter, deforestation, has consistently proven the most serious and intractable impact in forested areas. Deforestation may make financial sense in some settings, as it makes way for profitable activities, but there are always costs associated with forest conversion. Often the costs are public, such as loss of particular species, climate stabilization and watershed protection services, and therefore are unlikely to be defended by any particular individual or group.

If there is one infrastructure project that has come to symbolize the connection between roads and deforestation, it is Brazil's BR 364, which links the Amazonian states of Matto Grosso and Rondônia. Along with agricultural incentives and a network of feeder roads, this road opened the western Brazilian Amazon to massive colonization in the early 1980's. Financed in part by the World Bank, it sparked a vigorous debate about international funding for roads penetrating wilderness, indigenous areas and biological reserves. Fearnside (1987) charted the pace of deforestation in Rondônia from 1975, when 1,216 km^2 of forest was cleared, to the completion of the highway in 1984, when annual forest loss hit 13,955 km^2. In his study, Fearnside describes a "feedback loop" in which migrants gained access to an area via the road, moved beyond the end of the road and eventually exerted pressure for extension of the road to their new settlements.

There is empirical evidence to support Fearnside's suggestion that roads play a leading role in causing deforestation. In a statistical analysis of satellite data from 1978 to 1988, Pfaff (1996) found that paved roads in the Brazilian Amazon had a large and statistically significant impact on forest loss. Among variables over which policy-makers have some control, paved roads were *the* leading contributors to deforestation. The study found that unpaved roads were far less likely to cause deforestation. That finding suggests that BOLFOR's objective of promoting sustainable forestry could be significantly undermined by projects to pave the current earth and gravel road network in northern and eastern Bolivia.

In another study, Chomitz and Gray (1996) found that in Belize, access to market -- determined by a combination of distance and the existence of roads -- had a strong positive association with the clearing of land for agriculture. In neighboring northern Guatemala, analysis of satellite data revealed that most forest loss occurred along two established roads, and that "new clearing activity essentially stopped where the road ended." (Sader, et al. 1994). In a later article, Sader (1995) found that "90 percent of all new clearing and regrowth patches were within 3 km of known roads."

A similar analysis conducted by the Inter-American Development Bank (IDB) in the vicinity of a new access road in Latin America turned up similar results. Over a 15-year period, forests in the road's area of influence were reduced by 57 percent and were severely fragmented. Average patch size dropped from 50 ha. to 12 ha. (Tuazon 1994b). Another IDB study compared roads in settled and frontier areas. Though the data from the latter study are not suited to measuring actual forest loss, they do show the area of unclaimed "wildlands" legally incorporated into farms. In the previously settled areas, an average of around 26 ha. of wildlands were incorporated into farms per km. of road between 1980 and 1990. In the frontier areas, wildlands shrunk by more than 1,200 ha. per km. of road. That figure translates into an area of influence of 6 km. on either side of the road (Tuazon 1994b).

SECCION III
METHODOLOGY

In this paper, we examine three case studies using “rapid appraisal” methods to evaluate both the net economic benefits and the risk to forests and biological diversity. The outputs of these methods are estimates of the net present value (NPV) and internal rate of return (IRR)[1] of the projects, and information on the relative levels of species diversity and endemism in the ecological regions they traverse. Our interest in testing these methods stems from common problems with road planning in many countries. Comprehensive economic and environmental impact studies require detailed engineering specifications, field data related to biophysical conditions and other information. The high cost and time consuming nature of collecting this information often discourage planners from collecting it properly (in the case of biological data) and preclude early screening of projects. Early screening is important because once projects enter the detailed study phase, they often attract political backing that may prevail over more considered decision criteria.

The tools we employ in our analysis are the Highway Demand and Maintenance Standards Model (HDM) for the economic assessment, and Condor, an Arcview-based geographic information program, for the environmental assessment.

HDM is a computer model developed by the World Bank which simulates changes in road conditions and the cost of operating seven different classes of vehicles under those conditions. The net economic benefits are equal to the savings in transportation costs from the improvement in the road minus the initial and recurrent costs of making the improvement. We specify initial road conditions, construction and maintenance actions and their costs, traffic volumes and traffic growth. We also input market prices for vehicles and vehicle maintenance, interest rates and the length of the planning horizon.

Traffic data comes from the Bolivian *Servicio Nacional de Caminos* (SNC 1995). These data are gathered at pay stations throughout the country. We reduced the 10 vehicle types in the SNC data to the seven categories accepted by HDM. Traffic growth was projected based on linear time series regression analyses of growth trends over the period 1986-1994. Traffic specifically generated by the road improvement was assumed to be equal to 20 percent of the baseline traffic in two case studies and 50 percent in the other (the latter had very low baseline traffic). The rule-of-thumb assumption employed by planners for generated traffic is generally in the range of 20 to 40 percent (A. Menendez, pers. comm.). We also ran the model using generated traffic equal to 100 percent of baseline traffic to test the sensitivity of results. Sensitivity analysis was also done on project costs and on savings to road users. Fuel and oil prices were based on market prices in Bolivia in the second semester of 1996. Standard SNC assumptions for lowland roads were used for construction, maintenance, and vehicle costs (SNC 1996). We used a 20-year planning horizon and a 12 percent discount rate, both standard

[1]Net present value (NPV) and internal rate of return (IRR) are the standard measurements of an investment’s economic feasibility. To be feasible, a project must have a NPV greater than zero and an IRR greater than a specified market interest rate.

assumptions among SNC and development bank analysts.

The scenario simulated in all three cases was the paving of an existing gravel road. This choice was made because of limitations of the model in simulating improvements to earth roads. Some segments of the routes studied are actually earth roads, which would be more costly to pave. Our results may, therefore, overestimate true net benefits, especially in the first case study, where much of the route is comprised of poor quality logging roads. Clearly, there are many other kinds of road projects that could be simulated, including reconstruction, maintenance, and new construction in currently roadless areas. Our choice of scenario, however, is guided by our understanding of current priorities in Bolivia and by evidence cited above (Pfaff 1996) that paved roads are the ones most likely to conflict with the goals of forest management and conservation.

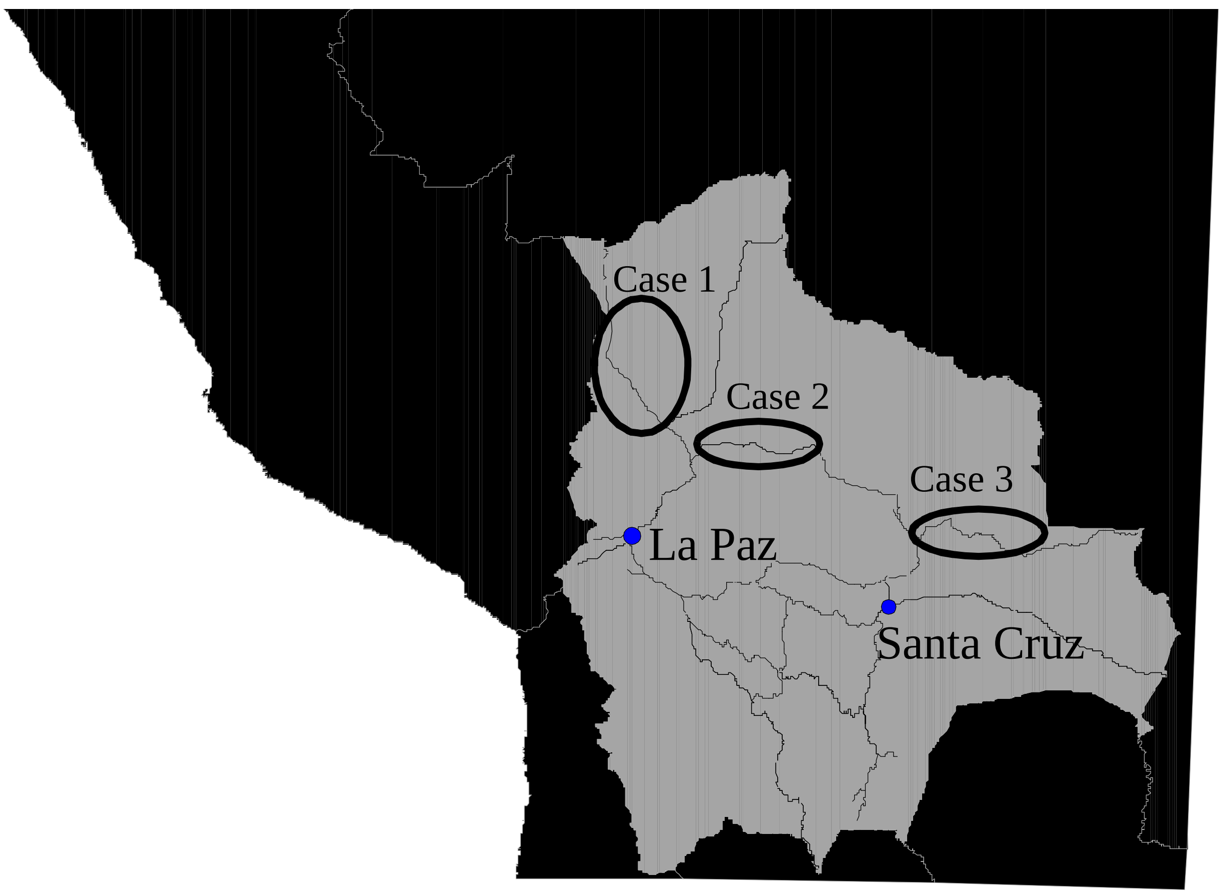
The environmental portion of the analysis narrows the question of potential impacts to an assessment of the biological diversity and uniqueness of the forest ecosystems that fall within the roads' areas of influence. The basis for this assessment is a map of "ecoregions" of Latin America compiled by Dinerstein, et al. (1995). These ecoregions are large areas with some level of ecological uniformity. After their definition, the ecoregions of the five tropical Andean countries (Bolivia, Colombia, Ecuador, Peru and Venezuela) were subsequently qualified by a working group of biological specialists.[2] This group classified the ecoregions in terms of their biological diversity (species, genera and habitat), endemism, vulnerability to change, overall biological "importance" and other factors. In this report, we use the measures of species diversity and endemism as indicators of the potential biological consequences of road projects. We also note, qualitatively, whether and to what degree the ecosystems in question are still intact or have already experienced significant human-caused change. The biological information is manipulated in the Condor computer program, developed by Conservation International.

Ideally, the two parts of this analysis would be integrated, with economic returns and biological costs expressed in the same units, dollars, for instance. Unfortunately, valuation of damage sustained by the environment must be calculated by methods that are not entirely reliable (See Vaughn and Ardila 1993) and can be costly to implement (See Freeman 1993 for a complete treatment of valuation methods). Instead, we perform the economic and biological assessments separately, though we intend for their results to be considered together in determining whether particular projects should be pursued.

[2]Working group meeting in Caracas, Venezuela, 1995, sponsored by the *Corporación Andina de Fomento* and Conservation International.

SECTION IV
CASE STUDIES

Three roads in Bolivia's forested lowlands were selected for case studies. The roads were chosen to represent different geographic regions of the lowlands and have all been identified as priorities by the Bolivian government (CAF 1993; World Bank 1992; Bolivia 1996). These roads all provide access to logging concessions and are used extensively for transporting timber. The first case is located in the relatively remote, undeveloped northwest corner of the country, in the northern part of La Paz. The second case examines a more settled area to the east, in the southern part of Beni. The third case focuses on the far eastern part of Bolivia, in a rural area of Santa Cruz with a long history of occupation. We toured these three roads, and visited a number of others to gain a perspective on the overall transportation network.



A. Case 1: San Buenaventura (Rurrenabaque) to Puerto Heath (Peru)

A1. Description

This 348 km. road is located in the northwestern part of the department of La Paz, at the foot of the Andes cordillera. Average rainfall ranges from 1,200 to 1,800 mm. along the route, and temperatures average 25 to 29EC. Soils under the flat Amazonian forest are orthic acrisols. On the steep slopes of the foothills, soils are dystric regosols, and in the river beds they are dystric gleysols. All three types pertain to the OL class of soils originally formed under grasslands, which tend to be somewhat fertile and capable of retaining nutrients. However, within their general class, these specific soils are all either heavily weathered or on the low end of the spectrum in terms of fertility, and therefore marginal for agriculture.

The route starts in the town of San Buenaventura, which is connected by ferry to the larger regional center of Rurrenabaque across the Beni river. The existing road follows mostly flat terrain punctuated by small streams every few kilometers. Because there are no culverts and very few bridges, motorists must reduce their speed to cross the streams, which adds significantly to travel time. The road is gravel from San Buenaventura to Ixiamas. Small agricultural clearings and fallows line the road, but in most cases extend no further than several hundred meters from the road. These plots have been cleared by colonists who migrated from the highlands after the road was constructed in the early 1980's. At Ixiamas, which predates the road, forest clearings shrink in size, reflecting the different agricultural practices of the region's traditional inhabitants. Beyond Ixiamas, a narrow earth road continues through pampas before entering into forest where little colonization has taken place. The road is passable as far as the Madidi river, which there is no means of crossing with a vehicle. West of the Madidi, there is reportedly a track of some sort going north toward the Peruvian border crossing at Puerto Heath.

The primary users of the road are logging trucks, which double as passenger transport vehicles taking rural residents to and from San Buenaventura. The trucks travel lightly loaded, apparently due to the stream crossings, carrying roughsawn lengths of mahogany (*Swietenia macrophylla*), cedar (*Cedrela fissilis*), and oak (*Amburana cearensis*). Loggers apparently take at least partial responsibility for maintaining the road; logging company workers were observed repairing a bridge over the Undumo river. The area is remote and very sparsely populated. Colonization that followed the road's construction was not sufficiently intense to provoke the opening of numerous feeder roads, as has been the case elsewhere in Bolivia. Apart from the towns of Tumupasa and Ixiamas, there are only scattered colonists in the region.

A2. Economic Benefits

Of the three roads studied, this one produced the least favorable financial results. We found that paving this route into Peru would produce a net present value of *negative* $25 million and an internal rate of return of -7 percent. Planners in Bolivia and elsewhere in the region usually require a

> Economic Benefits:
> San Buenaventura to Puerto Heath.
>
> Net Present Value: **-$25 million**
> Internal Rate of Return: **-7 percent**

positive 12 percent rate of return to judge a project financially viable. These results flow from the very low demand for transportation services in this part of Bolivia. The region supports a small human population, even where the gravel and earth roads have made access relatively easy. The simulation assumes a 50 percent jump in traffic generated by the improvement and 8 percent annual growth in traffic. These assumptions are more optimistic than those generally used by planners -- 20 to 40 percent for generated traffic and under 5 percent for annual growth. We simulated higher traffic volumes because of the extremely low current level of traffic on the road. It is possible that a high-quality paved road would spark a structural change in the region's economy on a scale that would make the project economically worthwhile, but evidence for such a shift is weak. Even when traffic is assumed to double with the completion of the road, the NPV only goes from -$25 million to -$24 million.

One problem is that the international link the road would make is not especially strategic in commercial terms. The Bolivian lowland towns of Yucumo, San Borja, Rurrenabaque, San Buenaventura, Tumupasa and Ixiamas would be linked with the Peruvian lowland town of Puerto Maldonado, whose economy is based on roughly the same set of agricultural and resource extraction activities as the those in the Bolivian towns. Furthermore, an easy connection already exists between Rurrenabaque, through Riberalta, to the Brazilian state of Rondônia, which already satisfies most of the trade needs that could reasonably be attended by lowland Peru. In any event, past studies have indicated that even the Rondônia route is a far less strategic export corridor than the east-west connection running from central and southern Brazil, through central Bolivia and on to the Pacific. A north-south trade axis is not considered to be a serious economic rationale for road development (World Bank 1993).

A3. Deforestation and Biodiversity Risk

<u>Forests and Biodiversity</u>. San Buenaventura to Puerto Heath.

Systems largely intact

Bolivian Yungas: Species richness **very high**; endemism **very high**.

SW Amazonian Moist Forest: Species richness **very high**; endemism **high**.

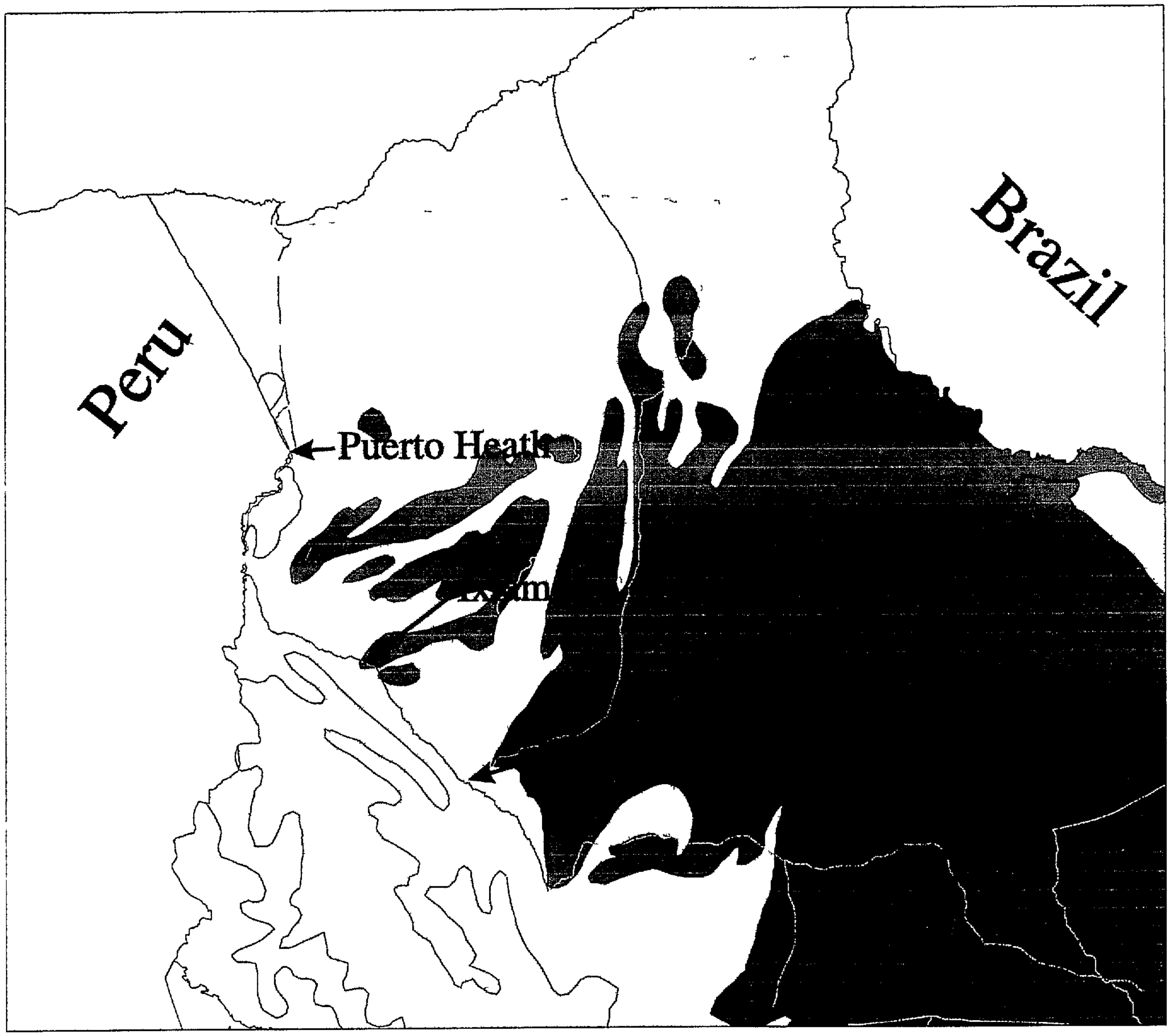
Beni Savannas: Species richness **medium**; endemism **high**.

This road lies in a transition zone between the Southwest Amazonian Moist Forest and the Bolivian Yungas ecoregions. The former system extends north and west into Brazil and Peru, though Dinerstein et al. (1995) suggest that the Bolivian portion is biogeographically distinct. The Amazonian region is characterized by large-stature broadleaf evergreen forest. Species richness is classified as very high and endemism is high. These flat areas are interspersed with areas of Beni Savannas, called "pampas" locally, where species richness is medium and endemism is low, but where the abundance of large vertebrates makes them a draw for Rurrenabaque's thriving tourist trade. The pampas are vulnerable because of their suitability for cattle ranching. The Bolivian Yungas system ranges from low-altitude moist forest to high-altitude cloud forest. The system is very high in both species diversity and endemism. This is due in part to the changes in altitude which isolate small, distinct biological niches. The forest canopy is almost entirely intact with the exception of a narrow band of agricultural land around the main road. However, there has been very extensive, highly selective logging of three timber species (mahogany, cedar and oak).

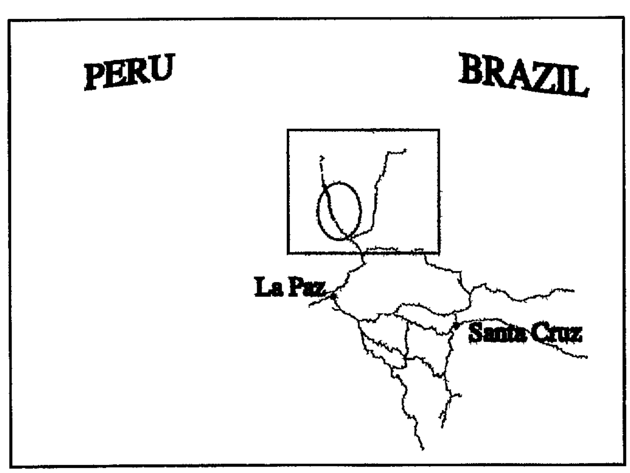
Physical effects of this logging appear to be minimal, but biodiversity effects are unknown.

The newly created Madidi National Park encompasses an area just to the south of the road. It comprises both Yungas and Amazonian ecosystems and is likely the area of greatest biological diversity in Bolivia, according to a 1990 rapid assessment of the region (Conservation International 1991). If a paved road existed to the north of the park, several other roads, which would threaten the park directly, would be more likely to be built. There is already pressure to construct a road into the park, from Tumupasa to San José de Uchupiamonas. Municipal leaders from Apolo, to the south have been pressing for a road connection to Ixiamas, which would bisect the park. And, recently, a logging road has been progressing toward the pristine upper Madidi river basin. Once its infrastructure, staff, and management plan are in place, the park may provide some measure of mitigation of indirect road impacts, but in its current state it would be vulnerable to negative impact from a nearby paved road. It is not possible to quantify biodiversity impacts of road development in the region, only to state that the array of species at risk through habitat loss here would be greater than in almost any other area of the country.

Map 1 - Species Richness
San Buenaventura - Puerto Heath

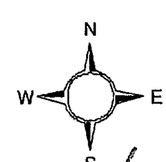


San Buenaventura-Puerto Heath
Other Roads and Road Projects

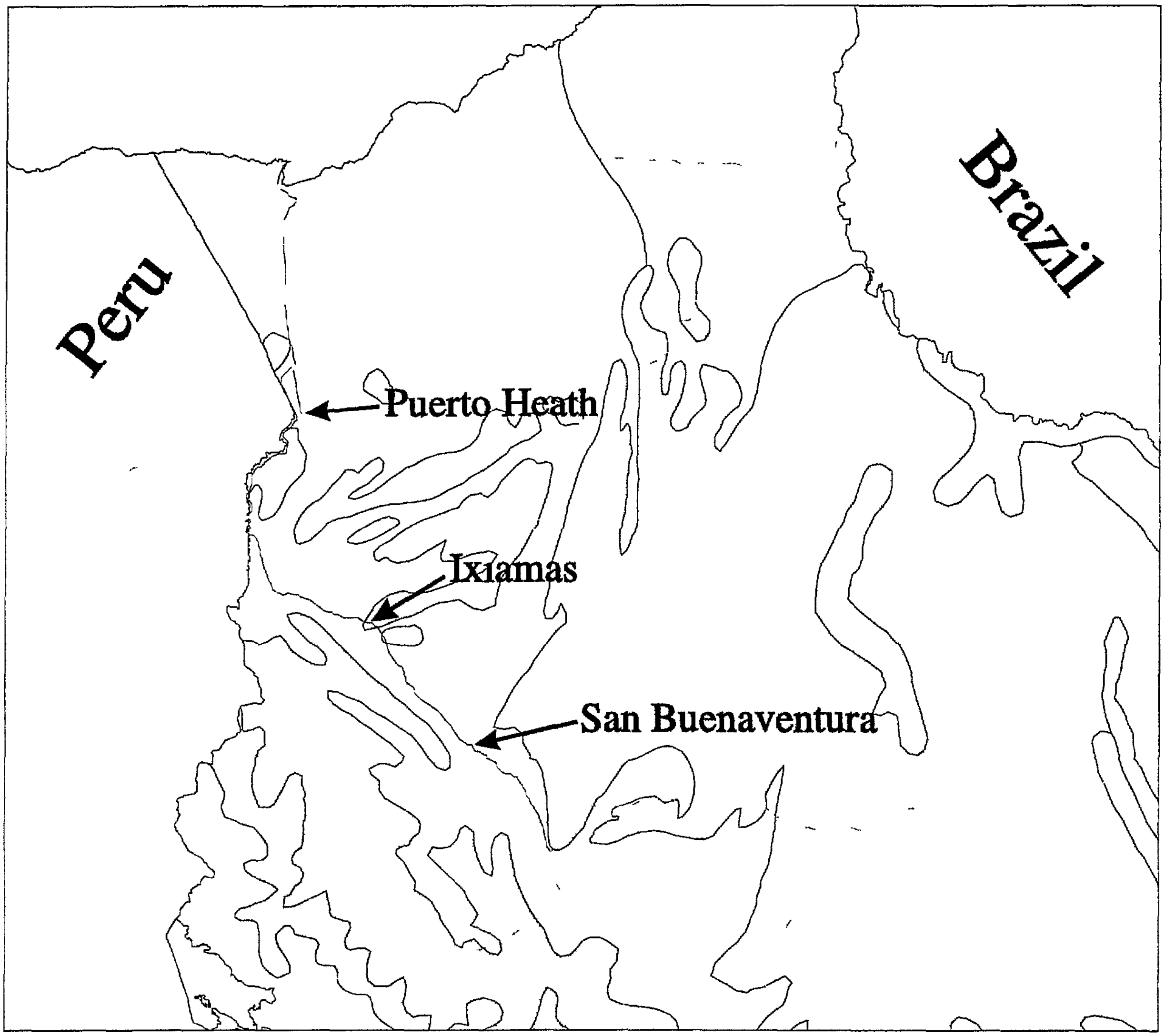


Species Richness by Ecoregion

- No Criteria
- Low
- Medium
- High
- Very High

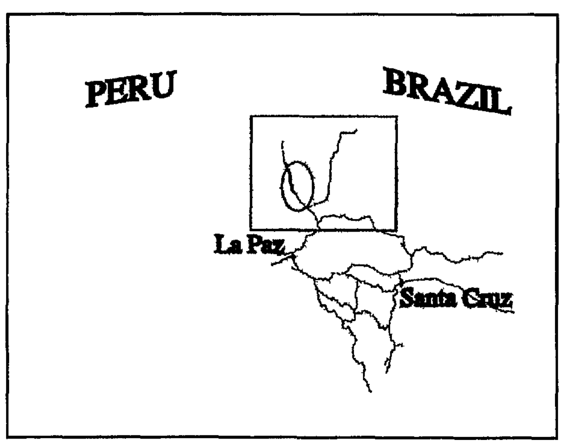


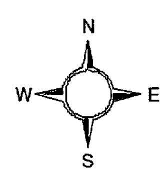
Map 2 - Endemism
San Buenaventura - Puerto Heath



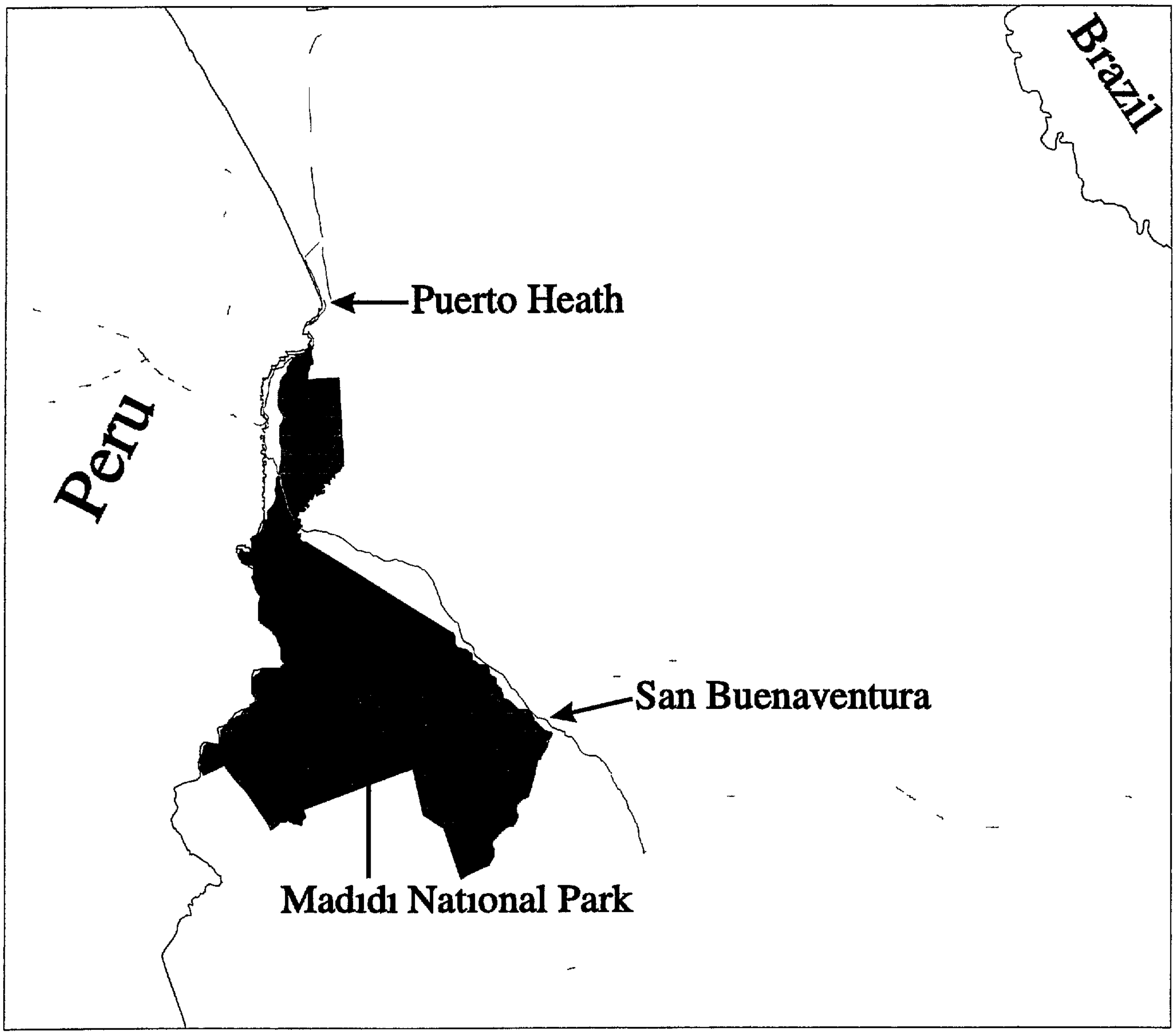
San Buenaventura-Puerto Heath
Other Roads and Road Projects

Endemism
- No Criteria
- Low
- Low-Medium
- Medium
- Medium-High
- High
- Very High

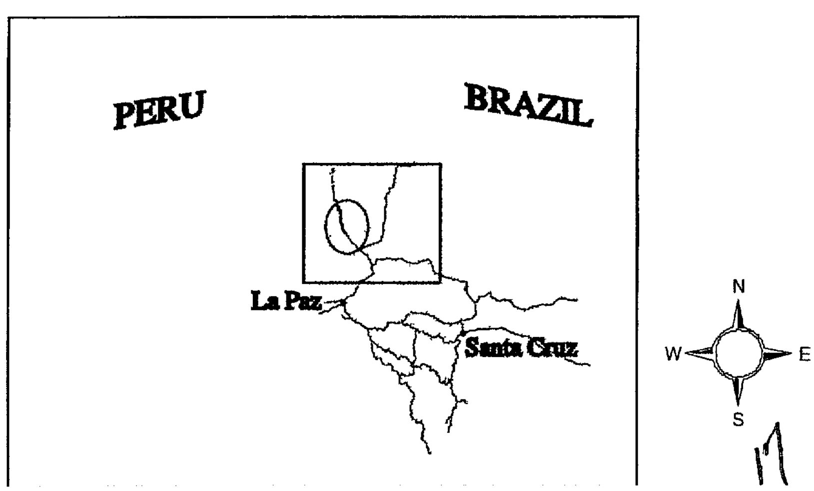




Map 3 - Madidi National Park and San Buenaventura - Puerto Heath Road



San Buenaventura-Puerto Heath
Other Roads and Road Projects
Madidi National Park



B. Case 2: San Borja to Puerto Ganadero (Trinidad)

B1. Description

This 211 km dirt and gravel road runs west-east through the southwestern region of Beni, better known as the Llanos de Moxos. Average rainfall ranges from 1200 to 1500 mm and temperatures average 25 to 29EC. Plinthic acrisols, characterized by deposits of hardened iron oxide and low fertility, predominate in the region. The area's topography is mostly flat with a few medium-sized silty rivers cutting across the road on their northbound flow. All of these rivers have concrete bridges spanning them, except the Tijamuchi which has ferry service. At Puerto Ganadero, the road to Trinidad is interrupted by the sprawling Rio Mamoré and its ever-shifting braided channel. This study left out the 17 km between Puerto Ganadero and Trinidad, because that road experiences a very different traffic pattern from the rest of the route. It links the city to the Rio Mamoré, where goods are loaded on boats for river transport.

The large natural grasslands of the Llanos de Moxos, as the area is called, have been used by extensive cattle ranches for many decades. Forests in this region are mostly islands surrounded by grassland, or gallery forests along the waterways. Large numbers of cattle are commonly herded along this road to market. The flat, low-lying region regularly floods during the rainy season (January-March), interrupting traffic for days at a time. Light pickup trucks, used by ranchers and merchants, are the main form of transportation. The road also sees a substantial flow of log trucks.

Human population is concentrated in the towns of San Borja and San Ignacio de Moxos, with several small communities of Mojeños (indigenous inhabitants) established along the road. This region hasn't seen the usual heavy influx of colonists along roads experienced elsewhere in the country, especially in the eastern lowlands. With the relatively recent availability of heavy machinery, ranchers have begun to drain their wetlands, plow them and plant annual crops, the long-term viability of which is as yet untested.

B2. Economic Benefits

> Economic Benefits: San Borja to Puerto Ganadero.
>
> Net Present Value: **$-3.7 million**
> Internal Rate of Return: **9.8 percent**

The NPV of the project came to $-3.7 million with an internal rate of return of 9.8 percent under our base case assumptions -- a 20 percent jump in traffic due to the project and 11 percent annual traffic growth. This road proves viable only under the very favorable assumptions of a 100 percent increase in traffic with the project and subsequent 15 percent annual increases over the twenty-year planning horizon. Under these conditions, the NPV would be $1.8 million and the IRR 12.9 percent. Sensitivity analysis showed that increasing project costs by 20 percent brought the IRR down to 8.1 percent, while a 20 percent reduction in savings to road users reduced the IRR to 7.7 percent.

The economic results make intuitive sense given the modest, but well-established economic centers along this road. The region has been settled for decades and has a stable base of cattle ranching. Also important is the fact that the route links the departmental capital, Trinidad, to La Paz, a link that will be further strengthened by completion of the new Santa Barbara to Cotapata road. Still, the region is too sparsely populated and there is too little demand for inter-departmental transport to justify paving. Furthermore, in the likely event that there are at least modest environmental costs associated with the road, it will not be viable from a social perspective. External social benefits will be scant given how few people live in between the main towns.

B3. Deforestation and Biodiversity Risk

> <u>Forests and Biodiversity</u>: San Borja to Puerto Ganadero.
>
> Systems substantially altered, especially grasslands.
>
> Beni Savannas: Species richness **medium**; endemism **high**.
>
> Beni Swamp and Gallery Forest: Species richness **medium**; endemism **low**.
>
> SW Amazonian Moist Forest: Species richness **very high**; endemism **high**.

This road passes primarily through the Beni Savanna and Beni Swamp and Gallery Forest ecoregions. Both of these areas rate as medium for species richness and low for endemism. A strip of Southwest Amazonian Moist Forest, described in the previous case study, intersects the road several times. The potential for forest biodiversity loss in this area is moderate compared to the San Buenaventura case, but still significant. One noteworthy ecological risk is the threat to the many lagoons, oxbow lakes and gallery forests in the region. These formations are rich in waterfowl -- *Jabiru mycteria, Egretta alba, Chauna torcuata, Mycteria americana, Porphyrula sp., Chloroceryle sp., Dendrocygna sp.,* etc. -- and are very sensitive to human disturbance. The areas would be likely to come under increased pressure as lower transport costs bolstered the trend of draining wetlands for large-scale farming.

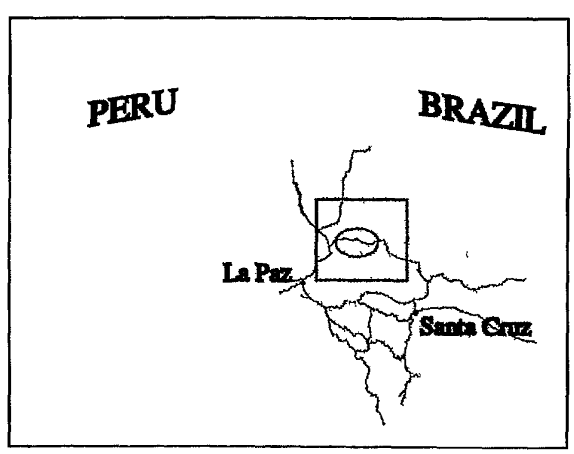
Map 4 - Species Richness
San Borja - Puerto Ganadero

San Borja-Puerto Ganadero

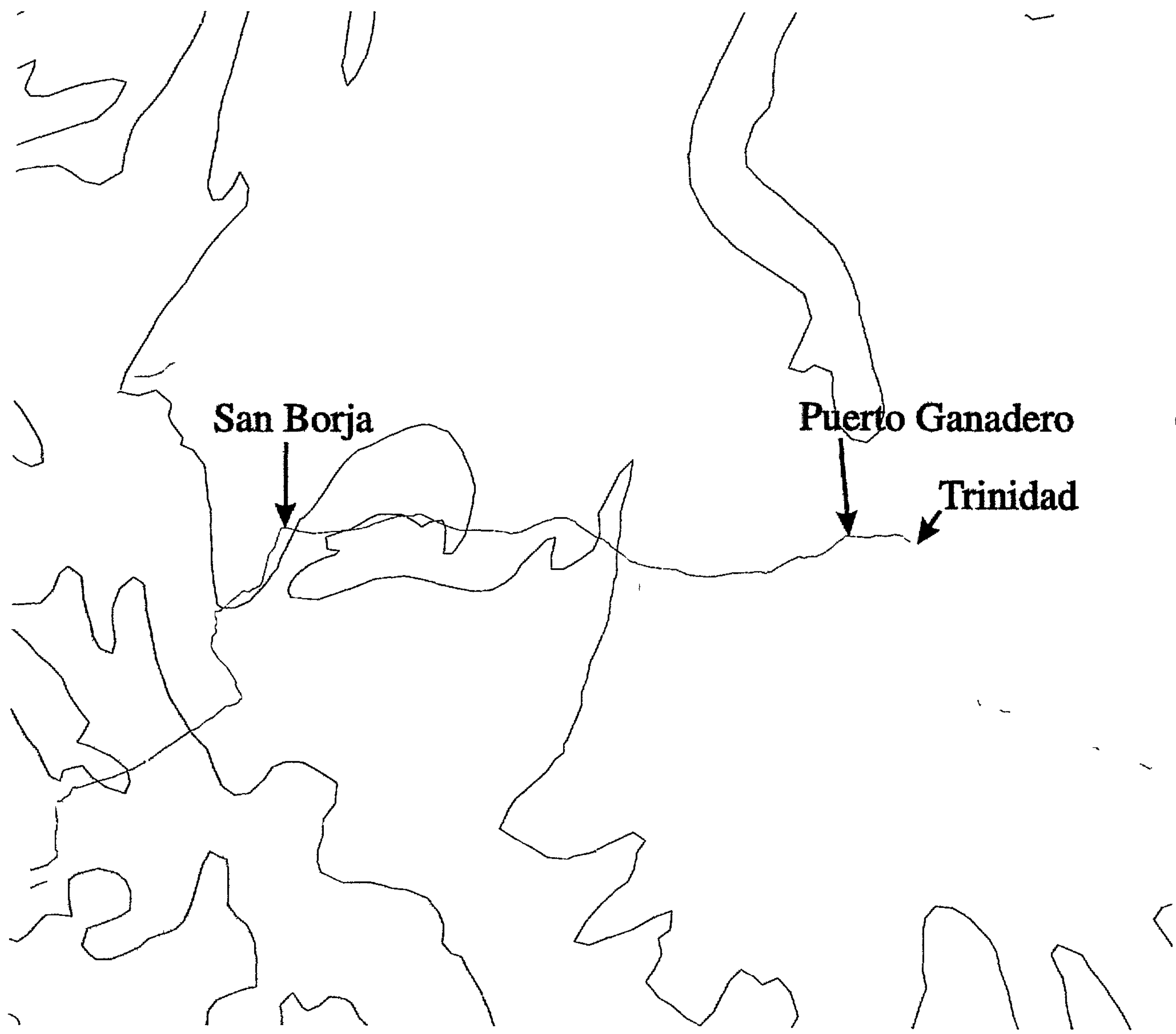
Other Roads and Road Projects

Species Richness by Ecoregion

- No Criteria
- Low
- Medium
- High
- Very High

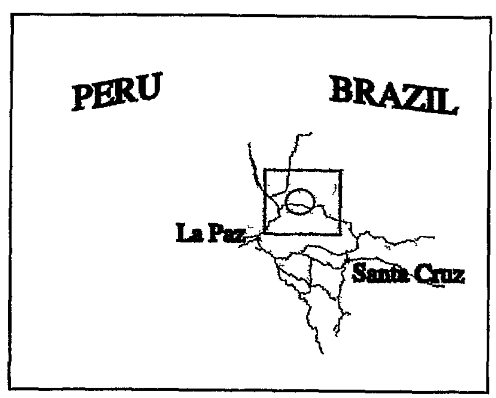


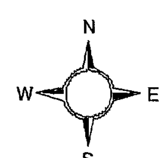
Map 5 - Endemism
San Borja - Puerto Ganadero



San Borja-Puerto Ganadero
Other Roads and Road Projects

Endemism
- No Criteria
- Low
- Low-Medium
- Medium
- Medium-High
- High
- Very High





C. Case 3: San Ramón to San Ignacio de Velasco

C1. Description

This 293 km road runs north from San Ramón to San Javier, then veers eastward through Concepción and Santa Rosa de la Roca before it reaches San Ignacio de Velasco. Rainfall along the route averages 1000 to 1500 mm. Temperatures average in the range of 25 to 29EC, for the most part, but in some areas exceed 30EC. The predominant soils are ferric luvisols, which tend to be somewhat fertile because they are composed of alluvial sediments. The stable gravel road traverses hill terrain partially covered with tropical deciduous and semi deciduous forest. The road facilitates the connection between Santa Cruz, the department capital, and Mato Grosso in neighboring Brazil.

The region, called Chiquitanía, has been settled for hundreds of years, starting with the arrival of Jesuits in the Sixteenth Century. Cattle ranching, logging, and agriculture, in that chronological order, have been the main economic activities. The land surrounding the road was mostly cleared of primary forest long ago. Most of it has been converted to pasture, with small scale agriculture and forest fragments following in importance. The five towns mentioned above are well established, with many more smaller communities and settlements at the roadside. Human presence is strong and growing along the entire stretch.

Presently, the main components of traffic flow are heavy trucks and light vehicles (cars and light pickups). Trucks transport timber, agricultural produce (mainly soybeans) to Brazil, and Brazilian manufactured goods into Bolivia. This international traffic crosses the border at the town of San Matías. Lighter vehicles serve the needs of small commerce and ranchers. Loggers use this road to access numerous timber concessions, where they are extracting "second-tier" timber species such as oak (*Amburana cearensis)*, cedar (*Cedrela fissilis)* and tajibo (*Tabebuia impetiginosa)*. The most valuable species, mahogany (*Swietenia macrophylla)* and morado *Machaerium scleroxylon)*, have been largely depleted (BOLFOR 1995).

C2. Economic Benefits

Of the three case studies, this one gave the best financial results. The NPV for this project is $4.8 million. The internal rate of return is 14.2 percent, above the 12 percent threshold. As with the other two case studies, the sensitivity of the results was tested by simulating a 100 percent increase in traffic due to the road improvement. The NPV increases to $13.11 and the IRR climbs to 16.9 percent. Even when construction costs increase 20 percent or user savings drop 20 percent, the IRR of the project hovers around the 12 percent threshold of acceptability.

> <u>Economic Benefits</u>: San Ramón to San Ignacio
>
> Net Present Value: **$4.8 million**
> Internal Rate of Return: **14.2 percent**

These positive results are due to the fact that the region is extensively occupied, so road improvements would have many beneficiaries. Just as important is the fact that this road would substantially complete a paved connection between the agricultural and industrial powerhouse of southern Brazil and all the important cities of Bolivia. The road is an alternative to the more southerly Santa Cruz-Puerto Suárez railroad, whose inefficiency and high-cost have spurred interest in a reliable road connection with Brazil. Average annual traffic growth of 11.8% on the San Ignacio route between 1987 and 1994 (SNC 1995), compared to national GDP growth of only 3.4% over the same period (IDB 1994), points to the importance of the road for the regional economy. A major road link may eventually take the same southern route as the railroad, however, this would leave the San Ignacio route at a disadvantage for serving southern Brazil. Nonetheless it would remain the most direct route to Cuiabá, the center for Brazilian soybean exports to the Far East.

C3. Deforestation and Biodiversity Risk

Forests and Biodiversity. San Ramón to San Ignacio.

Systems substantially altered, extensive human settlement.

Bolivian Lowland Dry Forest: Species richness **medium**; endemism **low**.

Cerrado (savanna woodland): Species richness **medium**; endemism **low**.

Humid Chaco and Chaco Savanna: Species richness **medium**; endemism **medium-high**.

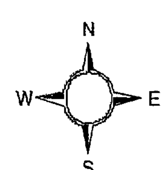
Paving this road could have major deforestation impacts, though perhaps not adjacent to the road itself. While much of the route has already been substantially altered by human occupation, paving the trunk road could facilitate colonization along numerous feeder roads which reach into areas currently used only by logging companies under concession agreements with the Bolivian government. Colonization of these areas may be a greater threat than in the Beni and La Paz cases, because of the traditional role played by the eastern lowlands in absorbing migrants from the altiplano. The ecosystems most immediately affected would be Bolivian Lowland Dry Forest and Cerrado (savanna woodland) ecosystems. The remnants of these areas rate as medium in terms of their species richness and low for endemism. Close to the road on the south are Humid Chaco and Chaco Savanna ecoregions which have medium species richness and medium-high endemism. Though the ecoregions immediatetly affected by this route are lower in biodiversity than moist forests elsewhere in Bolivia, it should be noted that the dry forest habitat types they represent have become rare in the Neotropics (Jantzen 1988). Land-use changes further afield could be more important for biodiversity at the species level. To the north of the road is an area of Rondônia/Mato Grosso Moist Forest, classified as high in species richness and endemism.

Map 6 - Species Richness
San Ramon - San Ignacio de Velasco

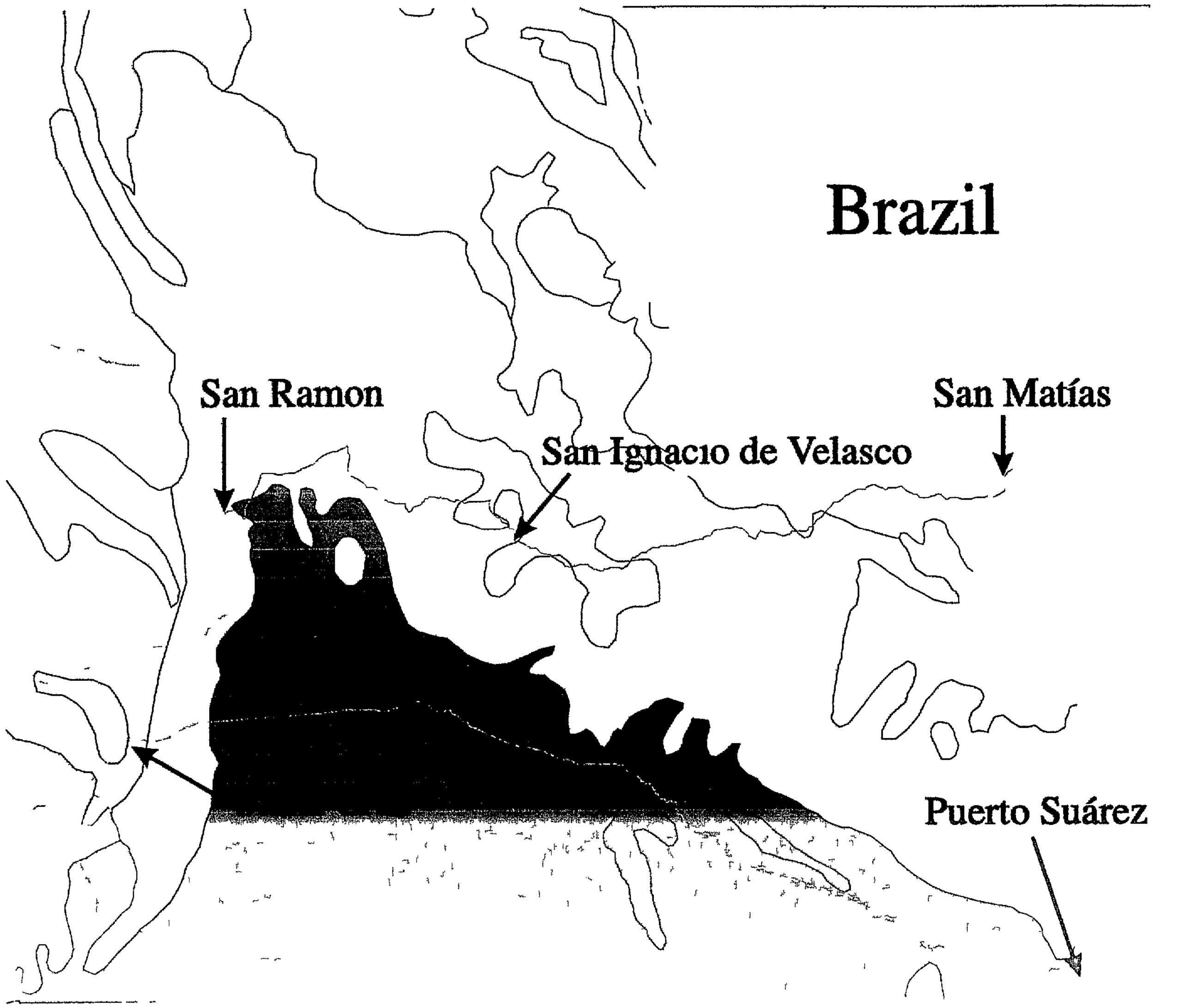
San Ramon-San Ignacio de Velasco
Other Roads and Road Projects

Species Richness by Ecoregion

- No Criteria
- Low
- Medium
- High
- Very High

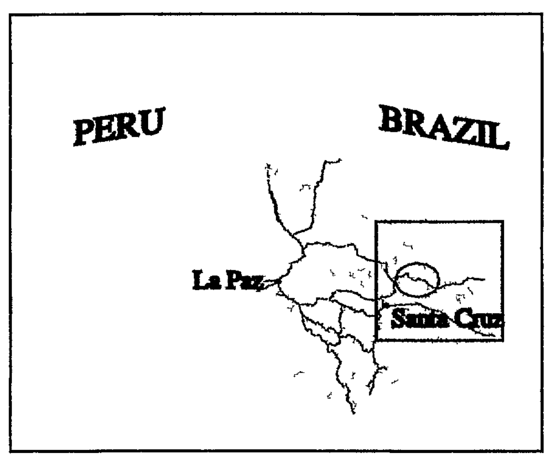


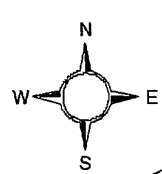
Map 7 - Endemism
San Ramon - San Ignacio de Velasco



San Ramon-San Ignacio de Velasco
Other Roads and Road Projects

Endemism
- No Criteria
- Low
- Low-Medium
- Medium
- Medium-High
- High
- Very High





SECCION V
DISCUSSION AND CONCLUSIONS

A. Case Studies

The case studies show that the economic viability and environmental impacts of roads vary from region to region in Bolivia's forested lowlands. The first case, involving road improvement to link San Buenaventura and Rurrenabaque to Peru at Puerto Heath, suggests that paving roads in remote northwestern Bolivia would be a money-losing proposition and would present a major new threat to the region's largely intact forests. In the second case, an east-west trunk road across the Beni is marginal, becoming viable only under assumptions that may be excessively optimistic. It is less environmentally threatening than the first road, but does put some key wetland and gallery forests at risk. The third case indicated that a road segment enhancing the connection between Santa Cruz and central Brazil would have stronger economic returns than the other cases and would present a moderate threat to biodiversity. However, the third road would put less-diverse forest types at risk, and could compromise areas dedicated to forestry by stimulating colonization along feeder roads.

B. Forestry

With respect to forestry, paved roads will most likely complicate the establishment of sustainable forestry as a stable, competitive land use. All three <u>un</u>paved roads we studied are already used by loggers and the roughest of the three is used almost exclusively by loggers. Paving would reduce the cost of moving logs, and could therefore make it economically feasible to extract lower-value tree species, but it would also make non-forestry land-uses more competitive. The comparative advantage of forestry in the absence of good road infrastructure is due to several factors. First, timber is relatively non-perishable, so transport time and reliability are not as important as they can be in marketing agricultural produce. Second, loggers do not need to establish permanent settlements in the forest, so they can do without the non-road infrastructure and services often made available by a paved road. Finally, the nature of timber extraction requires that loggers possess equipment to build roads, whether or not a paved trunk road exists. In remote areas loggers tend to keep roads and bridges passable on an as-needed basis using their own equipment, thereby exercising some control over access.

C. The Network Perspective

As we noted above, the economic analyses in this study are presented in artificial isolation from the universe of possible transportation investments that might be undertaken in Bolivia. To truly determine the wisdom of one or another investment, it is necessary to look at the whole transportation network and determine where the limited available resources will maximize benefits to society. Even though the third case study delivered a 14.2 percent internal rate of return, it may rank far below road maintenance projects, railroad improvements, airport expansion or paving projects elsewhere.

While a network analysis is beyond the scope of this paper, a few "big picture" observations can be made about transportation in Bolivia. First, the country is distinguished by vast distances and rugged terrain separating its cities (World Bank 1992). It is also remarkable for its low population density. Those facts make ground transportation of any kind very costly per passenger or per unit of cargo. The low volume of demand for transportation to many locations argues for a transportation mode with low fixed costs relative to its variable costs, such as air transport. The high fixed costs of installing pavement or railway between two places makes sense where there are sufficient potential volumes of passengers and cargo across which to spread those costs.

Second, the very limited extent of Bolivia's paved road network (1,462 km. in 1992) hints that there may still be many attractive paving investments to be made, but data on the condition of Bolivia's roads argues otherwise. In 1992, 74 percent of Bolivia's roads were classified as being in poor condition. The figure for the sparse network of paved roads was 36 percent (See Table 1). Analyses employing the same economic model used here found that road maintenance expenditures would outperform road construction by a wide margin. The average projected return on maintenance investments was 39 percent, while construction projects were expected to yield 11 to 28 percent at best (World Bank 1992). Since then, a World Bank project has attempted to reduce the maintenance backlog, so the difference may have declined.

Table 1: Condition of Primary and Secondary Road Networks in Bolivia in 1992

Contidition Surface	Good	Fair	Poor	Total
Paved	8%	55%	36%	100%
Gravel	0.2%	23%	77%	100%
Dirt	0%	10%	90%	100%

Source: World Bank 1992.

D. Siting

The case studies confirm a few simple intuitions about the location of road investments in the forested tropics. First, they suggest that there may be an inverse relationship between the economic benefits from roads and the risk they present to forest habitats. Clearly, there are numerous exceptions, but, other things equal, a road improvement in a somewhat settled area will benefit more people than will a road project in a sparsely populated wilderness. It might be argued that roads cause settlement in the first place and without previous projects, there would be no population to benefit from new projects. That argument misses the point that *today's* infrastructure planners must determine whether more economic benefits will be generated by extending the road network, or "intensifying" it with new investments in inhabited areas. Under Bolivia's current economic conditions, intensification appears to be the better investment. Schneider (1994) makes a related point in his investigation of land values at the Amazonian frontier:

"Intensification of the road network increases the price of adjacent land through reducing

transport costs and increasing farm productivity. Extensive roads opening new areas for exploitation will, by putting more land on the market, reduce the price of currently accessible land."

The second conclusion we can draw is that not all export corridors are equally strategic. In the most general terms, it is economically advantageous to link one country to another by various means. Some links, however, are not worth the cost and should not be built simply for the sake of physical integration. For example, paving several hundred kilometers to connect forest and pampas in northern La Paz and western Beni to the jungles of southeastern Peru does not make economic sense. It is too expensive and holds limited potential to unleash new economic activity. On the other hand, it does make sense to improve the connection between Bolivia's new economic hub, Santa Cruz, and the settled regions of Brazil. Whether the best route is through San Matías in the north or Puerto Suárez in the south is an open question.

E. Mitigating Indirect Impacts

This paper has suggested that there may often be win-win solutions in the siting of road projects. Projects in somewhat settled areas can have substantial economic benefits and do little ill to forest biodiversity. Sometimes, however, such a happy solution is not in the offing. Economically viable projects may need to pass through or near fragile natural areas. In these cases, the question of siting gives way to a question of appropriate measures to mitigate adverse environmental impacts. A few key considerations should be kept in mind when developing a mitigation plan.

Most fundamental is to focus at least as much attention on the indirect as on the direct impacts of the road project. Indirect impacts are those that are not physically caused by the project, but result from changes in land use within a certain zone of influence of the new or improved road. In remote natural areas, indirect impacts commonly dwarf the direct impacts of road building, but are neglected because they are not under the official control of the road-building agency or contractor. Furthermore, they are often spontaneous and difficult for *anyone* to control. And, unlike direct road construction impacts, someone benefits from the indirect impacts -- farmers gain access to land.

A first step to controlling these impacts is to establish strategically placed protected areas that will ensure that key ecosystems are conserved as a region becomes more accessible. This strategy has proven successful in Costa Rica, where the Brualio Carrillo National Park protects rain forest bisected by the road linking the capital, San José, to the Caribbean coast. It has also worked in Venezuela and is now being tried in a section of Brazil's highly endangered Atlantic coastal forest.

The specific protected areas strategy should be matched to the circumstances of each road. In a region with both well-protected and unprotected forest, it may be advisable to run the road through the protected area, where land-use regulations are strict and simple. In a place such as the Madidi region, a declared park may need to be equipped, staffed and consolidated before it can serve the purpose of mitigation. In other circumstances, as in the stretch of Brazilian coastal forest mentioned above, an Inter-American Development Bank project has taken the approach of creating a new park to protect most of the region's remaining forest.

Protected areas will not always succeed in mitigating indirect road impacts, especially where other, conflicting governmental agendas intervene. Amboró National Park, for example, was set up in part to contain the impact of planned road improvements between Santa Cruz and Cochabamba. The road, however, was the focus of colonization efforts that brought a wave of migrants to the vicinity of the park. As a result, many of the more accessible, lower elevation areas of the park have been turned over to farmers. The Amboró experience points to the need to harmonize other government policies with the road's mitigation plans.

F. Rapid Assessment as a Planning Tool

One purpose of this study was to test a method for rapidly assessing economic and environmental aspects of road projects without the benefit of costly engineering and environmental impact studies. The ability to do so could greatly improve the planning and prioritizing of road investments as it would allow planners to size up projects before political and institutional momentum had gathered for any particular investment. We conclude that with some further development our method could be quite useful. One opportunity for improvement is to create region-specific, standardized HDM input templates that would contain as many constant parameters as possible. The model requires such a large array of data to run that it is anything but rapid unless many of the basic inputs are provided for the region in question. We found that the Condor program, which is new, performed satisfactorily.

The most obvious shortcoming of this method, noted above, is its inability to put projects into the larger perspective of a country's overall transport needs and a full range of possible investments. However, there is probably no rapid means of doing that. Another flaw that may be difficult to overcome is that actual biodiversity impacts are not projected. Instead, we are limited to characterizing the levels of uniqueness and biodiversity of the ecosystem that will experience the impacts of the road, whatever those impacts may be. But even sophisticated biogeographical studies have trouble pinning down with certainty the numerical relationship between habitat loss and species loss, so, in the context of a rapid appraisal methodology, little more can be done than distinguish between regions that have more and less to lose should their natural habitats be altered.

SECTION VI
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ANNEX I
SUMMARY AND HDM OUTPUT TABLES

HDM Manager Project Summary

Project: Paving San Buenaventura (Rurrenabaque) - Puerto Heath
Road Length: 348 km
Currency: millions of US dollars

Inputs

Average Daily Traffic-ADT (vehicles)	14
Projected Annual Traffic Growth Rate (%)	8
Generated Traffic	O.5*ADT

Outputs

Total Economic Cost (discounted)	47.5
Project Net Present Value at 12% Discount Rate	-25
Project Internal Rate of Return (%)	-7
Internal Rate of Return (20% increase in agency costs)	-8
Internal Rate of Return (20% decrease in user benefits)	-8.2

Project: Paving San Borja - Puerto Ganadero (Trinidad)
Road Length: 228 km
Currency: millions of US dollars

Inputs

Average Daily Traffic-ADT (vehicles)	69
Projected Annual Traffic Growth Rate (%)	11
Generated Traffic	O.2*ADT

Outputs

Total Economic Cost (discounted)	59.8
Project Net Present Value at 12% Discount Rate	-3.7
Project Internal Rate of Return (%)	9.8
Internal Rate of Return (20% increase in agency costs)	8.1
Internal Rate of Return (20% decrease in user benefits)	7.7

Project: Paving San Ramon - San Ignacio de Velasco
Road Length: 293 km
Currency: millions of US dollars

Inputs

Average Daily Traffic-ADT (vehicles)	91
Projected Annual Traffic Growth Rate (%)	11.8
Generated Traffic	O.2*ADT

Outputs

Total Economic Cost (discounted)	132.8
Project Net Present Value at 12% discount rate	4.8
Project Internal Rate of Return (%)	14.2
Internal Rate of Return (20% increase in agency costs)	12.2
Internal Rate of Return (20% decrease in user benefits)	11.7